

A search for distant X-ray galaxy clusters

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Abstract. We report on the progress of our search for serendipitous distant X-ray galaxy clusters in the ROSAT PSPC pointed observations archive. The initial aim of our work is to measure the X-ray luminosity function of clusters down to $f_{lim} = 4 \times 10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1}$ and so test the claims of cluster evolution at moderate redshifts. We have R band images and spectroscopy for 45 extended sources detected in 50 of the 100 deepest southern fields. A preliminary analysis suggests we cover a range of distances, from nearby clusters to possible distant clusters, $z \simeq 1.0$.

1. Introduction

One of the major goals of cosmology is to probe the evolution of structure with lookback time. Galaxy clusters play a key role in this ambition because:

- Their formation by gravitational collapse is understood well enough to allow comparisons of observations with theoretical predictions of density evolution.
- They can be observed out to cosmologically significant distances ($z \simeq 1.0$) and so provide an important probe of the conditions in dense environments at early times.

Optically selected distant cluster catalogues (e.g. Gunn et al. 1986; Couch et al. 1990) are plagued by selection effects such as cluster mis-identification due to line of sight projection effects (Frenk et al. 1990). X-ray cluster selection greatly reduces such effects and produces cleaner, statistically better defined samples (Henry 1992).

Two recent surveys measured the X-ray luminosity function (XLF) and found that there are fewer X-ray bright clusters at $z \simeq 0.1 - 0.3$ than locally (Edge et al. 1990; Henry et al. 1992). This result, if true, is of major consequence to our understanding of cluster evolution (e.g. Kaiser 1991). Unfortunately the conclusions are tentative because the surveys become seriously incomplete at the redshifts where the evolution is seen.

The increased spatial resolution and sensitivity of the ROSAT PSPC detector compared to previous X-ray imaging satellites and its low background rate mean that we can measure the cluster XLF at fainter fluxes. We

can therefore test both the claims of cluster evolution and measure the shape of the local XLF. Several groups are working towards this goal (e.g. RIXOS, RDCS & WARPS), each using different cluster selection methods. As yet, there is no agreed method for detecting clusters in X-ray imaging data and so it is important for independent surveys to investigate different selection algorithms. A comparison of these surveys is given in Table 1.

Table 1. A comparison of distant X-ray cluster surveys.

Name	$f_{lim}^\dagger / 10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1}$	Ω / deg^2
This Project	4	14
EMSS	~ 10	40
RDCS	1	26‡
RIXOS	3	15‡
WARPS	7	13‡

[†] Flux limits are for the 0.5 - 2.0 keV band.

[‡] Areal coverage as given in Rosati 1995, Castander et al. 1995 and Jones et al. 1995.

2. Source Selection

To combat the severe contamination expected from stars and AGN at our survey depths (Stoeckle et al. 1991), our primary selection criterion is source extension. As clusters have significantly harder spectra than the general population of X-ray sources (Ebeling 1993) we use source hardness as a secondary selection criterion. The analysis is restricted to the 0.5-2.0 keV band, to reduce the contamination from soft sources, and to the central region of the PSPC detector, where the PSF does not change significantly with off-axis angle. We are concentrating on the 100 deepest pointings which satisfy:

- $T \geq 10\text{ks}$
- $|b| > 20^\circ$
- $\delta < 20^\circ$

Analysis begins with screening out periods of bad aspect error or high particle background. We then compute a

global estimate for the background and search for sources using the Cash statistic (Cash 1979). Sources are tested for extent by comparing the photon distribution to the PSF, taking care to model both the positional and spectral dependence of the PSF. Monte Carlo simulations show that we can reliably use source extent as a discriminant within the central region ($r \leq 18'$) and that we expect to be 90% complete out to $z \simeq 0.5$. All sources which have an extended profile are selected for optical imaging and spectroscopy, during which hardness ratios are used to help identify the X-ray source.

3. Optical Follow Up

We have analysed 50 ROSAT fields and our initial observing run, using EFOSC on the ESO 3.6m, produced R band images and spectroscopy for the extended sources in these fields. These sources can be characterised as:

- Pairs of stars with small projected separation.
- Nearby clusters with $z < 0.3$.
- Imaging suggests a cluster, but spectroscopic confirmation was not possible. We estimate, from the brightest galaxy magnitudes, $z = 0.3 - 0.5$.
- Sources with no obvious identification even after imaging to $R \simeq 22$.

We show, in fig 1, one of our distant cluster candidates. Spectroscopy of the central galaxies suggest $z = 0.55$. Fitting the X-ray spectrum by a Raymond-Smith plasma code, with $T=6$ keV and half solar metallicity, gives $L_X \sim 3 \times 10^{44}$ erg s $^{-1}$ (0.5-2.0keV).

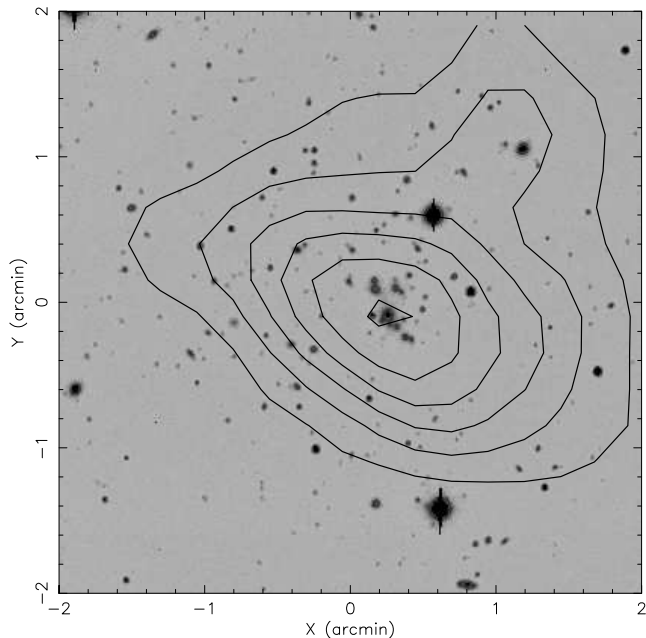


Fig. 1. X-ray contours (lightly smoothed) overlaid on R band image. At $z = 0.55$ 1 arcmin equals $440h_{50}^{-1}$ kpc ($q_0 = 0.5$).

4. Future Work

The initial goal of this work is to measure the cluster XLF. We have time allocated to complete the identification and spectroscopy of our remaining fields. Time has been applied for to secure identification and redshifts of our unconfirmed cluster candidates. As we suspect our unidentified sources may well be distant clusters, we have applied for K band imaging. This will allow us to identify clusters and we can use the K-z diagram (Collins & Mann 1995) to estimate cluster redshifts with sufficient accuracy for construction of the cluster XLF.

Our collaboration is also using a wavelet-based detection algorithm to search for clusters in the deepest Northern ROSAT pointings. Optical follow up of these extended sources has begun on the ARC 3.5m telescope at Apache point. We will therefore be able to use our two well defined catalogues to directly compare selection techniques and assess our completeness.

Future work will investigate the relationship between the hot intracluster gas and the optical properties of clusters and to study the Butcher-Oemler effect (Butcher & Oemler 1984). Our sample, combined with other distant cluster catalogues currently being compiled (e.g. RIXOS, RDCS and WARPS), will make an excellent target list for AXAF and the upcoming 8m class of ground based telescopes.

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